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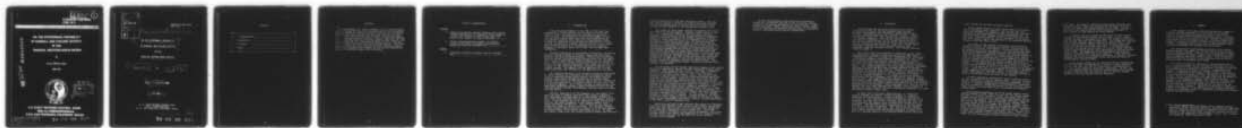
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ON THE INTERANNUAL VARIABILITY OF RAINFALL AND CYCLONE ACTIVITY--ETC(U)  
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**JTWC 74-5**

**ON THE INTERANNUAL VARIABILITY  
OF RAINFALL AND CYCLONE ACTIVITY  
IN THE  
TROPICAL WESTERN NORTH PACIFIC**

**BY**

**1LT J.F. PRATTE, USAF**

**MAY 1974**

**AD A 064539**

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9 Technical note  
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## ABSTRACT

Rainfall amounts at various stations in the tropical North Pacific during the dry season (January-April) were correlated with the number of tropical cyclones occurring in the western North Pacific areas during the same year from 1959 to 1973. Correlations were made for each rainfall station individually and for various group of stations. Results indicated that the best correlation was shown with rainfall on Guam, however, the relationship was poor (correlation coefficient of 0.24) and not sufficient for long-range forecasting purposes. The study also provides a survey of various articles relating tropical circulation patterns and rainfall to sea surface temperature anomalies and other large scale influences.

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## 1. INTRODUCTION

Since the establishment of the JTWC in 1959 there has accumulated a fairly reliable set of tropical cyclone data obtained from a centrally directed warning and reconnaissance program. An examination of the annual number of tropical cyclones reveals that some years are characterized by considerable activity while others are comparatively light. A study was conducted to investigate the possibility of forecasting the degree of tropical cyclone activity in any season. Such forecasts could be of considerable use for planning purposes if available early and if they could be made with confidence.

Frequent repetition or persistence of anomalous circulation patterns during a season or adjacent seasons has often been noted by mid-latitude meteorologists. Behind these deviations from the normal or climatological pattern often lies the reason for a winter's harshness or summer's drought over an extended area. Namias (1972, 1969a) described the effect on climate of large-scale sea surface temperature (SST) anomalies and the persistence of the resulting anomalous circulation pattern over several seasons. He suggests that an important key to long-range prediction lies in analysis and application of SST data.

The simplest approach to the forecast problem at hand would be identification of a parameter or set of parameters which could be measured several months before the primary tropical cyclone season (June through November) in the western North Pacific) and serve as an indicator of the extent or intensity of a large-scale persistent circulation regime favorable for tropical cyclone genesis. As is often the case in meteorology, such approaches inherently assume a gross oversimplification of the real atmospheric systems; nevertheless, they may serve as useful starting points.

Rainfall appeared to be the parameter to investigate first since the data is readily available from climatic summaries. Its measurement has been made at a large number of fixed stations with long continuous records and a good geographic distribution. Though rainfall may be an indicator of many interacting factors, few other parameters in the tropics exhibit such a large interannual variability. This variability can equal or exceed that found in the mid-latitudes. For instance, monthly rainfall amounts have differed by a factor of 20 or more between successive years in the central equatorial Pacific. At Guam, the current study shows that annual rainfall amounts have deviated

from the mean by 25 to 35% over the past 15 years. The very fact that a station's rainfall is influenced by many factors may be advantageous since it allows the qualitative consideration of many elements of the atmospheric system at once.

The causes of these large rainfall fluctuations have been the subject of several papers. Bjerknes (1969) refers to the SST - air temperature difference favoring upward moisture transport and increased rainfall during periods of anomalously high SST at Canton Island in the central equatorial Pacific. Relatively minor fluctuation of air temperature occur between the months of potentially heavy rain, so the high rainfall periods seem to be determined almost exclusively by the SST. Furthermore, differences on the order of  $2^{\circ}\text{C}$  in SST account for the excessive interannual rainfall differences noted above. A relationship between SST and rainfall in the Guam area should also include the effect of large scale subsidence resulting from upward motion and convection nearby and in other near-equatorial areas such as Indonesia or New Guinea. This effect was suggested by Krueger and Gray (1969) who noted the suppression of rainfall in some parts of the central equatorial Pacific during a period of abundant rainfall at Canton Island. They further noted an interesting inverse relationship between wind constancy and rainfall.

The occurrence of the unusual warm water regime in the central and eastern equatorial Pacific has been documented several times (Bjerknes, 1969; Quinn and Burt, 1972). This area is normally noted for its anomalously cool water and cloud-free skies (Laviolette and Seim, 1969; Sadler, 1970). Both rainfall and cloudiness increase when the normal tradewind-induced upwelling decreases in this region. Quinn and Burt (1972) used the sea level pressure difference between the East Indies and eastern South Pacific (better known as the Southern Oscillation) as a forecasting tool for rainfall at near-equatorial stations. A pressure drop in the eastern South Pacific signals a weakening of the anticyclone, diminishing trades, and consequent loss of or reduction in equatorial cool water upwelling. It is of interest to note that the anomalous periods of rainfall only occur during the northern hemisphere winter season. At this time, the southern hemisphere anticyclone is weakest. Climatologically, the equatorial cool water tongue stretches at least as far west as  $160^{\circ}\text{E}$  longitude and consequently may effect tropical cyclone development in the JTWC's area of responsibility.

Laviolette and Seim (1969) indicate that regions of extremely warm water have existed in the western North Pacific area during summer and that SST over  $32^{\circ}\text{C}$  are not uncommon, even though the mean summertime temperatures do not exceed  $30^{\circ}\text{C}$ . Since the monsoon trough is primarily a heat-induced phenomenon, SST in the tropical Pacific may affect the extension of the trough eastward from the Asian continent and the ease with which tropical cyclones can be spawned.

Several meteorologists have described relationships between the circulation patterns of the westerlies and the occurrence of tropical cyclones in the low latitudes. Namias (1969b) and Orgill (1960) illustrate typical 700-mb anomaly charts of high and low tropical cyclone months in the North Atlantic and western North Pacific respectively.

## 2. DISCUSSION

Rainfall data was collected primarily from climatic summaries published by the Environmental Data Service, National Oceanographic and Atmospheric Administration and by local communications with the stations involved. January through April departures from average were summed to yield a "dry season" departure. The tropical western North Pacific area generally experiences its dry season during the first four or five months of the year which are also the months of minimum tropical cyclone activity. These "dry season" departures were computed for eleven selected stations with reasonably long and continuous records. The stations used are listed in Table 1.

The results were then examined in comparison to the yearly fluctuations in tropical cyclone activity in the JTWC area of responsibility from 1959 through 1973 (FLEWEACEN/JTWC, 1959-1973). A reasonable coherence was displayed, especially for later years. Also considered were averages of several stations at a time. Interestingly, the Guam rainfall variations demonstrated by far the most consistent correlation with the tropical cyclone fluctuations. The rainfall departures from three Guam stations (NAS Agana, Andersen AFB, and Guam WSO) were averaged together to suppress measurement errors and local effects. Figure 1 is a time series displaying the average Guam "dry season" rainfall departures, the frequency of tropical cyclones, and the frequency of tropical storms (including typhoons). It is useful to note two items in particular, the fine coherence since 1967 and the inverse correlation of 1963. The large differences between the tropical cyclone and tropical storm frequency of early years may have been introduced by more subjective and liberal methods of assigning the term tropical depression to a disturbance. Other indicators of a tropical cyclone season's activity were compared with rainfall, such as number of warnings per year, however, the best correlations appeared to be with the yearly tropical storm totals.

To apply this correlation quantitatively to forecasting, scatter diagrams of tropical cyclone frequency vs. rainfall departure were constructed. A typical diagram is illustrated in Figure 2. The correlation coefficient between tropical storm frequency and Guam "dry season" rainfall departure was only 0.24 and represents the highest value obtained from several pairs of variables. The abnormally heavy precipitation of the dry season of 1963 is difficult to explain. This feature and the comparative dryness of early 1960, 1964, 1965, and 1966 (the five data points which cause most of the scatter in Figure 2) appear to be part of a general pattern in the western North Pacific reflected

in the records of the other stations examined.

Ramage (1968) points out that January 1963 was characterized by extremely heavy convection and rainfall over the "maritime continent" of Indonesia, and the efficient northward transport of heat maintained an intense subtropical jet. In the succeeding winter, drought conditions prevailed over the same area. The precipitation and the intensity of the Hadley cell were closely tied to the strength of the northeast monsoon, strong in 1963 and weak in 1964.

The effect of the Southern Oscillation and the central equatorial Pacific SST warming were briefly investigated for possible correlations with tropical cyclone activity and clues to reducing the scatter in Figure 2. No firm connections were discovered between the limited available Southern Oscillation (and central Pacific equatorial warming) data and the numbers of tropical cyclones forming in the entire western North Pacific area, in the South China Sea only, or the numbers of tropical cyclones forming east of  $165^{\circ}\text{E}$  longitude where the effects of any central Pacific equatorial sea surface warming should be most evident. It was hoped that the number of tropical cyclones that formed east of  $165^{\circ}\text{E}$  and south of  $15^{\circ}\text{N}$  might serve as a rough measure of the amount of extreme eastward extension of the monsoon trough. Since one limb of the Southern Oscillation is anchored in the Indonesia area (Bjerknes, 1969), it was hoped that its effect might appear in the distribution of tropical cyclones in adjacent areas both north and south of the equator.

Southern Hemisphere (Australian) tropical cyclone activity was not evaluated for lack of adequate data. Since the tropical cyclone season there overlaps the period of measurement of this study (i.e. January through April) interhemispheric connections may have altered the convective activity in the tropical western North Pacific from that which would be produced by indigenous factors alone.

A qualitative examination of 700-mb height anomaly charts (Monthly Weather Review, 1960-1973) for the "dry season" months and years of interest revealed a rather consistent connection between western North Pacific subtropical ridge heights and the amount of Guam rainfall. This link seemed to follow reasonably well during the problem years of 1960 and 1963 through 1966. Elevated heights imply a stronger anticyclone, stronger trades, possibly lower SST in the tropics, and reduced tropical convection. The relationship between wind speed and SST is determined primarily by evaporation, convective transfer of heat, and sea surface layer mixing (Laevastu and Hubert, 1965). Lighter winds (lower wind constancy) from a weak anticyclone favor not only higher SST but also growth of shower clouds over large islands

like Guam. The synoptic conditions which permit frequent weak frontal system or shear line penetrations southward also may result in a lower than average height of the ridge. Convection and significant precipitation often accompanies passages of these systems at Guam during the winter months.

It appears that an increase in the amount of "dry season" rainfall at Guam occurred about 1959 or 1960. The "dry season" rainfall average at NAS Agana rose about 25% between the periods 1948 through 1959 and 1960 through 1973. This change may coincide with a minor climatic change indicated by Namias (1972). Year-to-year variations in rainfall were also of larger amplitude during the second period than the first. It is interesting to note that the average yearly number of tropical storms reported in the western North Pacific also experienced an increase around 1959 or 1960. The magnitude of the interannual fluctuations likewise increased after 1959 (see Figure 1). These features, however, may be due to increased surveillance of tropical cyclones, stemming from the establishment of the JTWC and the advent of meteorological satellite data.

Total annual rainfall at the Guam stations was examined and demonstrated some correspondence to tropical cyclone frequency for the same year, but not as satisfactory a correspondence as the "dry season" departure previously considered. In fact, the rainfall departure for the tropical cyclone season (June through November) did not even correlate as well as the "dry season" departure with the tropical cyclone frequency.

### 3. SUMMARY

There appears to be some connection between the number of tropical cyclones generated in a given year in the western North Pacific area and the amount of rainfall received at tropical stations during the preceding "dry season". Possible connections between the activity of the tropical cyclone season and persistence of the monsoon trough, sea surface temperature anomalies, tropical rainfall, strength of the subtropical anticyclone, the Southern Oscillation, and interhemispheric connections were mentioned with considerable speculation.

The quantitative relationship described in this article between rainfall and number of tropical storms is not suitable for forecasting purposes. However, the fair qualitative correspondence depicted in Figure 1 suggest that examination of additional parameters may yield useful results. Lack of satellite data prevented the analysis of cloud patterns for the years in which the worst correlations were found.

The effect of tropical convection, and associated latent heat release and export, on mid-latitude circulations has often been suggested; but the reverse connection, the effect of systems in the westerlies on tropical convection, is apparently more obscure. A preliminary study of tropical cyclone formation reported by Hamilton (1974) suggests that pulses in the strength or location of the subtropical ridge, determined by mid-latitude systems, affects the horizontal low level shear and the formation of storms in the tropics. Ramage (1968) pointed out that weather in the Indonesia-Southeast Asia region is strongly modified by events in the mid-latitudes, but then the intensity of the mid-latitude circulation regime may be influenced by the response from the tropics.<sup>1</sup> Evidently the problem is complex but further investigation of the above areas and of long-range forecasting may eventually result in reasonable prediction of seasonal tropical cyclone activity.

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<sup>1</sup> In a recent paper, White and Walker (1973) compared several equatorial and mid-latitude atmospheric parameters and concluded that the meridional teleconnections proposed by Namias (1969) and Bjerknes (1969) operated rather sporadically during the period 1950-1972, and suggested, based on their results, that a change in atmospheric mode occurred about 1963.

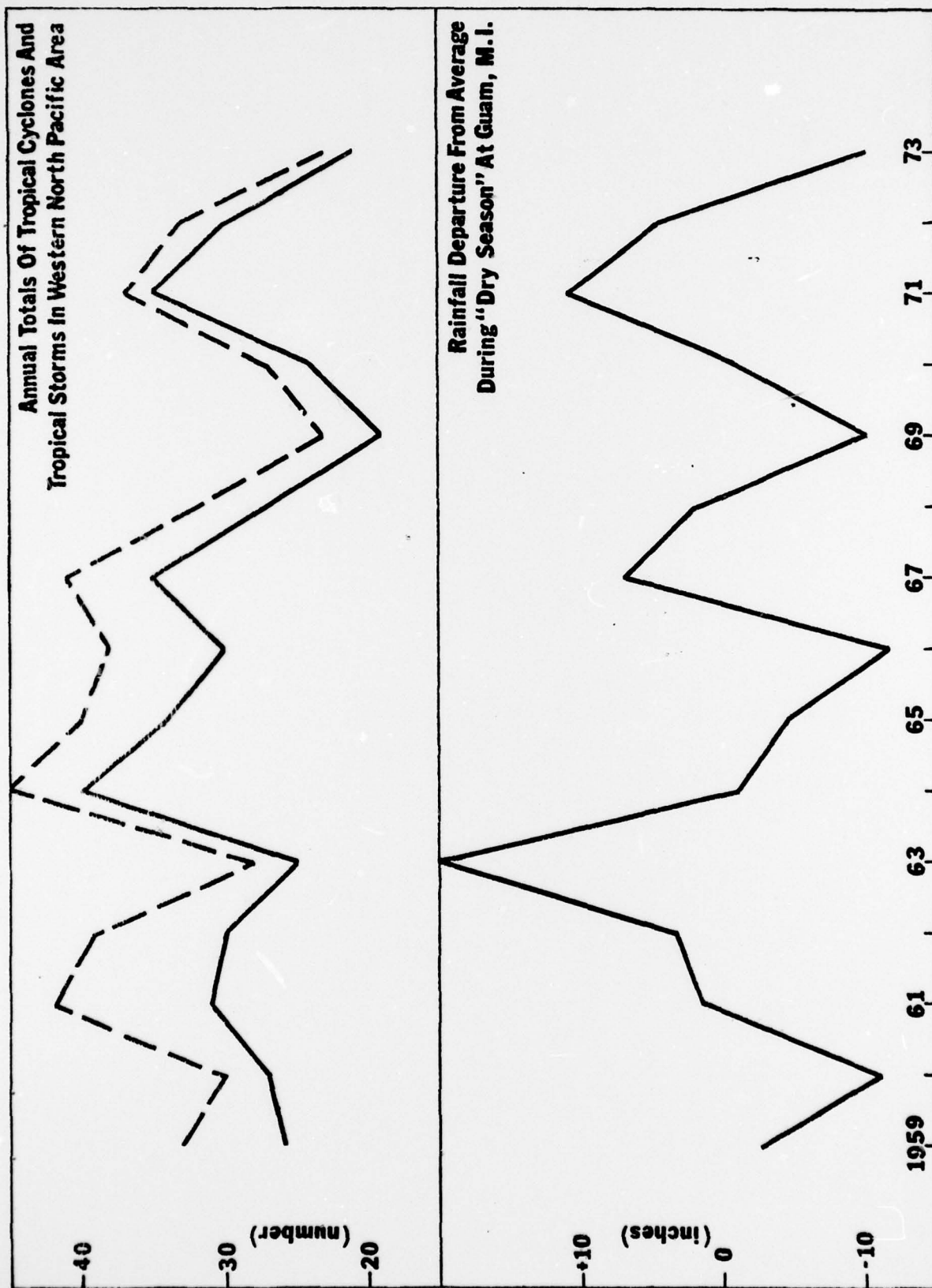


Figure 1. Numbers of tropical cyclones (dashed) and tropical storms compared with the departure from average of rainfall (in inches) at Guam during first four months ("dry season") of years indicated.

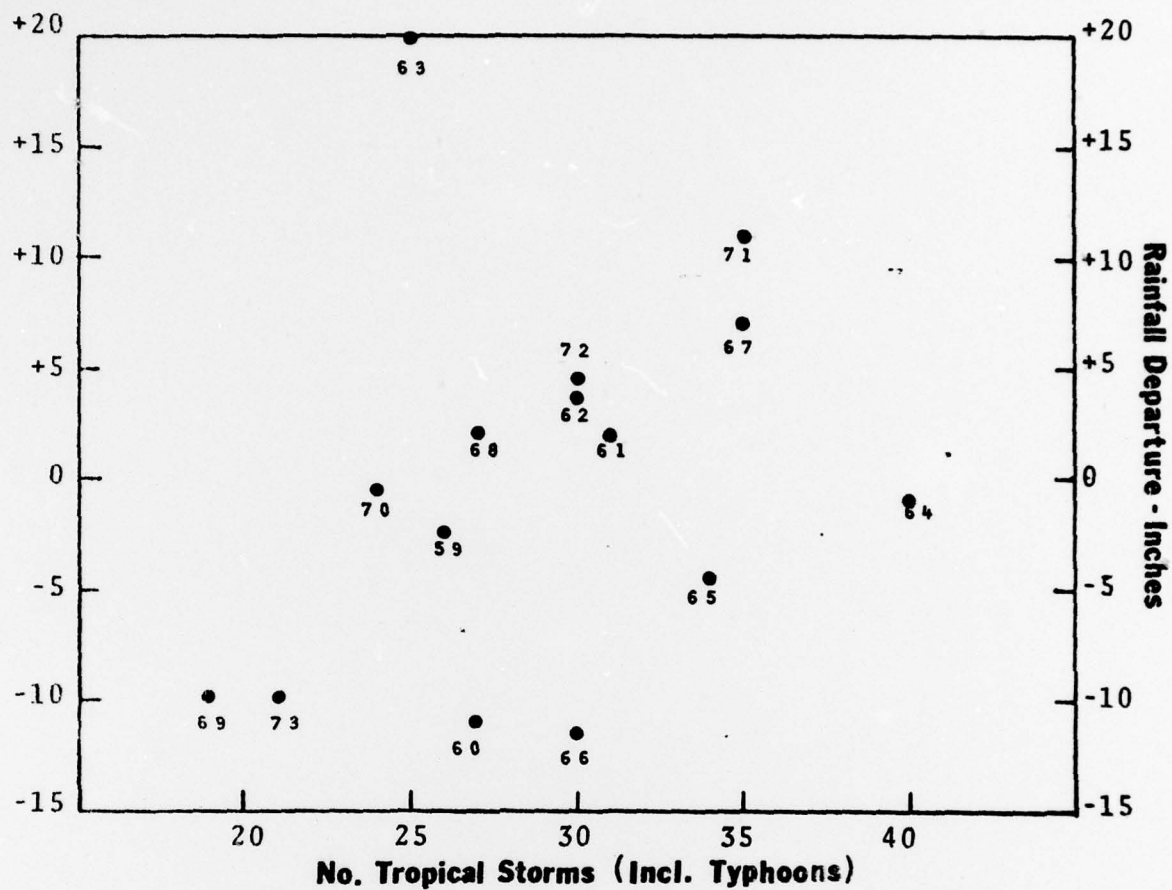


Figure 2. Scatter diagram depicting number of tropical storms versus Guam "dry season" precipitation departures from 1959 through 1973.

Table 1. LOCATIONS OF PACIFIC STATIONS USED FOR RAINFALL DATA

<u>STATION</u>	<u>WMO</u> <u>IDENTIFIER</u>	<u>LOCATION</u>	<u>ELEVATION</u>
NAS Agana	91212	13°29"N 144°48"E	094 m
Andersen AFB	91218	13°35"N 144°55"E	191 m
Guam WSO	91217	13°33"N 144°50"E	111 m
Hilo	91285	19°43"N 155°03"W	011 m
Honolulu	91182	21°20"N 157°55"W	004 m
Koror	91408	07°20"N 134°29"E	029 m
Kwajalein	91366	08°43"N 167°44"E	002 m
Lihue	91165	21°59"N 159°21"W	045 m
Majuro	91376	07°05"N 171°23"E	003 m
Truk	91334	07°28"N 151°51"E	002 m
Yap	91413	09°29"N 138°05"E	016 m
Wake	91245	19°17"N 166°39"E	004 m

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